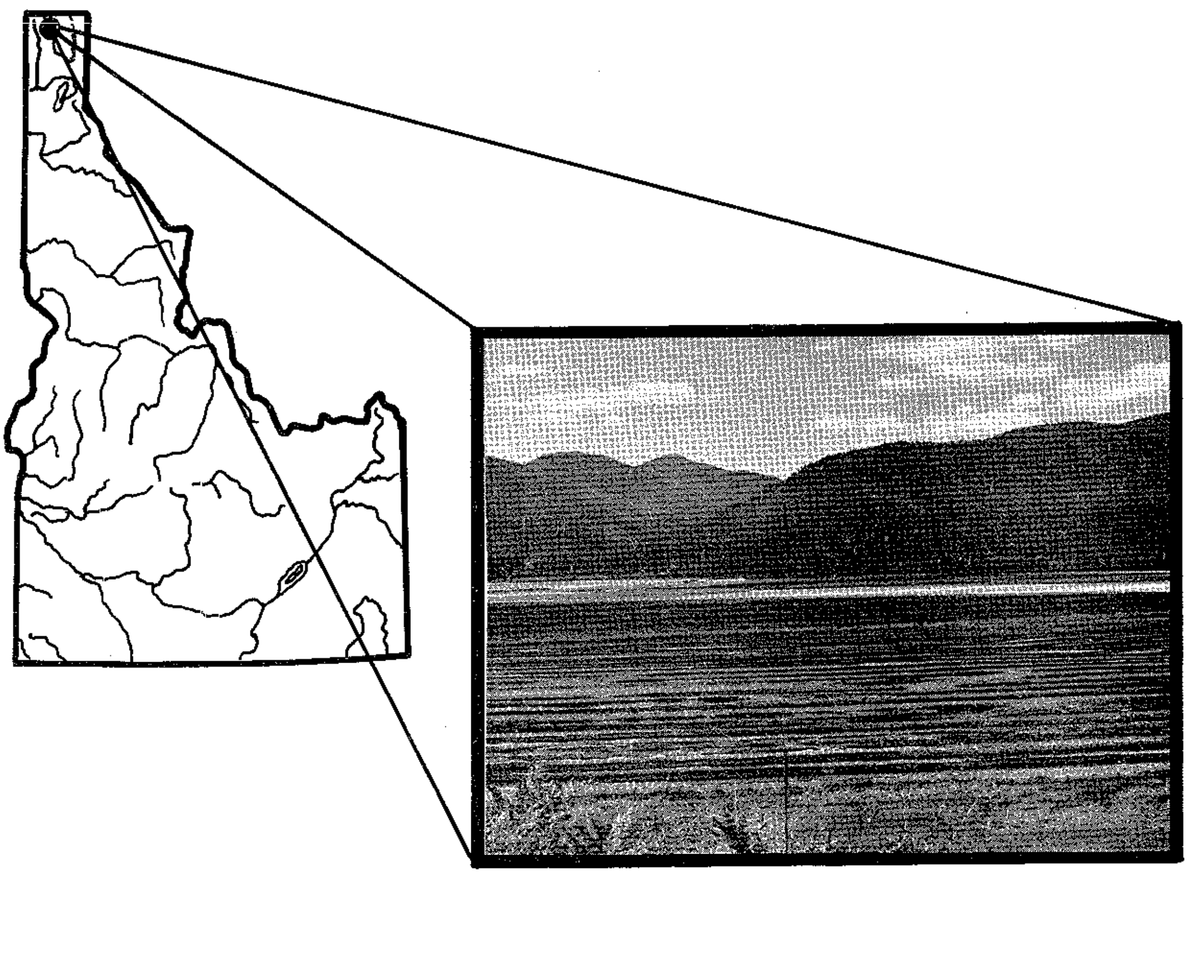
A GROUND - WATER MONITORING NETWORK FOR KOOTENAI FLATS, NORTHERN IDAHO



IDAHO DEPARTMENT OF WATER ADMINISTRATION

WATER INFORMATION BULLETIN NO. 33

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A GROUND-WATER MONITORING NETWORK FOR KOOTENAI FLATS, NORTHERN IDAHO

by

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Prepared by the United States Geological Survey

in cooperation with the

Idaho Department of Water Administration

Published by

R. Keith Higginson

Director

December 1973

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N. P. Dion and R. L. Whitehead

ABSTRACT

The water table in the fine-grained sediments of the Kootenai flats area, Idaho, is very shallow and is influenced in part by the stage of the Kootenai River. The operation of newly-built Libby Dam, near Libby, Montana, will change the long-established patterns of river-stage and, consequently, of water-table fluctuations. To measure the effects of the new river-stage regulation on the ground-water system, a network of 82 shallow and two deep observation wells was established on the Kootenai flats in 1971.

A large amount of information pertaining to the ground-water system of the Kootenai flats was collected by the U. S. Geological Survey and others between 1928 and 1958 and is presented in a number of informal progress reports prepared during that time period. This report describes the nature and availability of the information that was collected as part of these earlier investigations.

A comparison of the ground-water levels measured during 1930-54 with the few levels measured in the new observation wells indicates that no significant trends in water-levels have occurred in the area since measurements were discontinued in 1954.

INTRODUCTION

Background

The water table in the part of the Kootenai flats area lying between Bonners Ferry and the international boundary (fig. 1) is shallow and is influenced, in part, by the stage of the meandering Kootenai (spelled Kootenay in Canada) River. The stage of the river is determined both by discharge and by backwater effects of Kootenay Lake in British Columbia. The stage of Kootenay Lake is controlled for hydroelectric power production and flood control by Corra Linn Dam which is west of Nelson, British Columbia.

In 1930, just prior to the construction of Corra Linn Dam, the U. S. Geological Survey installed 300 shallow observation wells in the Kootenai flats to monitor the effects of the impending change in river stage on the ground-water system. Periodic water-level measurements were made in those wells between 1930 and 1958, and the seasonal pattern of ground-water fluctuations became well known. Farmers in the area adjusted to and relied on this familiar pattern of fluctuations in their agricultural operations.

The operation of newly-built Libby Dam, near Libby, Montana, and upstream from the Kootenai flats, began in March 1972. This operation will change long-established patterns of river-stage and, consequently, of water-table fluctuations. Operation of Libby Dam will serve to regulate the flow of Kootenai River with the result that seasonal fluctuations in discharge of Kootenai River below Libby Dam will be decreased significantly (fig. 2). Consequently, river stages will be considerably higher than normal between November and March, just prior to the time when maximum efforts are usually exerted by farmers to lower the water table by draining to prepare their fields for spring planting. The higher river levels in winter will reduce

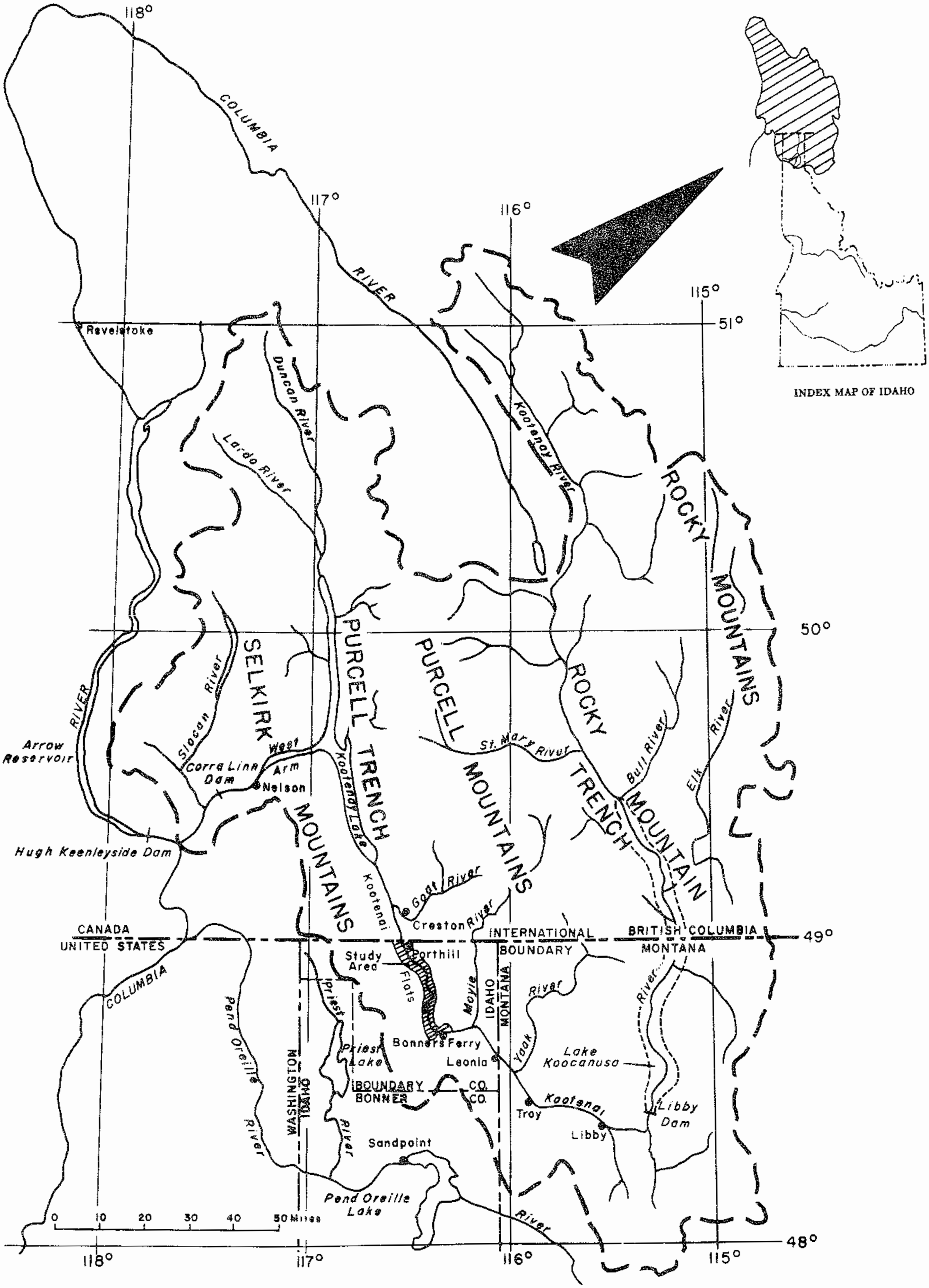

FIGURE 1.--Regional index map showing location of study area.

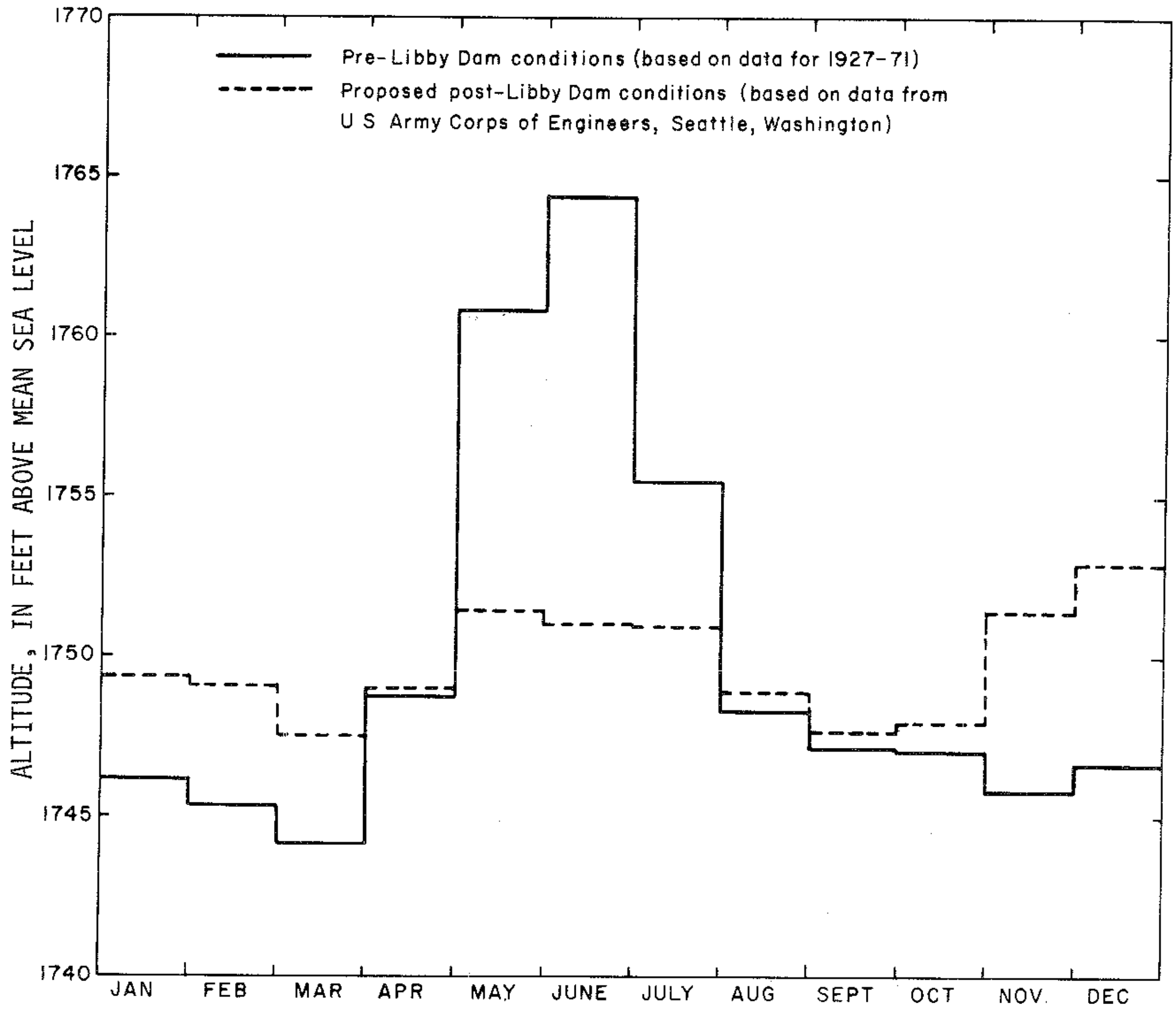

FIGURE 2.--Mean monthly stage of Kootenai River at Bonners Ferry.

natural ground-water discharge and the flow of water through gravity drains to Kootenai River, thereby causing ground-water levels to be higher in some drainage districts. Several gravity drains that were operable for several months under pre-Libby Dam conditions will be inoperable for the entire year under post-Libby Dam conditions and additional pumping of drain water will be required. Many farmers in the area, fearing an increase in seepage to their fields and the loss of gravity drainage from their fields, have expressed concern over the fate of their agricultural operations. However, some drainage districts will experience little change in seasonal ground-water level and in required pumping from drains because of the new river-stage regulation; other districts probably will experience reduced pumping. Prior to the summer of 1971, the effects of the new river-stage regulation on the ground-water system could not be measured because the observation wells installed in 1930 had been destroyed or were no longer suitable for measurement.

A large amount of information pertaining to the shallow ground-water system of the Kootenai flats area was collected by the Geological Survey and others between 1928 and 1958. Much of this information has been released in progress, administrative, and basic-data reports, many of which were not published and, therefore, received little or no circulation. For this reason, the need for a bibliography listing the types of hydrologic data available, the location and status of the data, and their availability to the public has been expressed.

In cooperation with various governmental agencies in Idaho, the U. S. Geological Survey studies and reports on the water resources of the State. The Idaho Department of Water Administration has a need for knowledge of Idaho's water resources as a part of its designated responsibilities. Both the Geological Survey and the Idaho Department of Water Administration recognized the need to monitor the effects of Kootenai River regulation on the water table of the Kootenai flats and to compile a bibliography of available information pertaining to that area. For these reasons, the study summarized in this report was completed in 1971 by the Geological Survey in cooperation with the Idaho Department of Water Administration.

Objectives of Report

The objectives of this report are to: (1) Present an observation-well network established in the Kootenai flats area to provide accurate, current information on ground-water levels; (2) compile a bibliography of interpretive and basic-data reports available for the area; (3) describe in condensed form the hydrology of the Kootenai flats; and (4) relate the water-levels measured in the new and old (1930) wells.

Location and General Features

The Kootenai River rises in the Rocky Mountains of Canada, flows through the United States by way of Montana and Idaho, and turns back into Canada to enter Kootenay Lake (fig. 1). The river is the third largest tributary of the Columbia River and is more than 400 miles long. The drainage area of the Kootenai River is about 19,500 square miles, of which 5,000 square miles are within the United States.

There are three distinct mountain systems within the basin, the Rocky, Purcell, and Selkirk Mountains. The Rocky Mountains lie on the east side of the drainage basin and are separated from the Purcell Mountains to the west by a long depression known as the Rocky Mountain Trench. The Purcell Mountains are separated from the Selkirk Mountains to the west by another depression known as the Purcell Trench.

The Purcell Trench has a length of about 180 miles in British Columbia and about 120 miles in Idaho. At Bonners Ferry, Idaho, the Kootenai River emerges westward from a terraced valley into the Purcell Trench and, curving northward, flows in a meandering course through broad, flat bottomlands known as the Kootenai flats. The river eventually empties into Kootenay Lake in British Columbia, after having flowed a distance of about 50 miles across the Kootenai flats. The altitude of the Kootenai flats is about 1,750 feet above mean sea level. The eastern half of the Purcell Trench in Idaho is occupied by a terrace known as the Porthill bench (fig. 3). This bench ranges in altitude from 2,100 to 2,300 feet above mean sea level and is 350 to 550 feet higher than the Kootenai flats. The Selkirk and Purcell Mountains, which rise steeply on either side of Purcell Trench, have altitudes of more than 8,000 feet.

Kootenay Lake occupies about 65 miles of the Purcell Trench. The lake ranges in width from 2 to 5 miles and has an area of about 180 square miles. Maximum depth of the lake is about 450 feet. Drainage from the lake is westward through the West Arm, past the town of Nelson, British Columbia, and into the Columbia River.

Large parts of the Kootenai River flood plain in Idaho have been artificially diked and drained for agricultural purposes. Drainage districts have been formed and are administered by local landowners. Drainage is by gravity into the Kootenai River provided the stage of the river is below the outlets of the drains. During periods when the river stage is above the drain outlets, drain gates are generally closed to prevent flooding and drain water is pumped into the river. The locations of the principal pumping stations, as well as the names and numbers of the drainage districts, are shown in figure 3.

The principal crops grown on the flood plain are grains, peas, and hay. Irrigation is uncommon, but occasionally the drain gates are closed in an attempt to retard drainage and thereby subirrigate the crops.

The principal town in the Idaho part of the Kootenai River drainage is Bonners Ferry, which had a population of about 1,900 in 1970.

Use of Metric Units

In this report, metric units are used to report air temperatures. This change from reporting in "English units" has been made as a part of a gradual change to the metric system that is underway within the scientific community and is intended to promote greater uniformity in reporting of data. Air temperatures are reported in degrees Celsius (°C). Table 1 will help to clarify the relation between degrees Fahrenheit and degrees Celsius.

Table 1. Temperature-conversion table.

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-8.0	17.6	6.0	42.8	16	60.8	26	78.8	45	113
-6.0	21.2	7.0	44.6	17	62.6	27	80.6	50	122
-4.0	24.8	8.0	46.4	18	64.4	28	82.4	55	131
-2.0	28.4	9.0	48.2	19	66.2	29	84.2	60	140
0	32.0	10	50.0	20	68.0	30	86.0	65	149
1.0	33.8	11	51.8	21	69.8	32	89.6	70	158
2.0	35.6	12	53.6	22	71.6	34	93.2	75	167
3.0	37.4	13	55.4	23	73.4	36	96.8	80	176
4.0	39.2	14	57.2	24	75.2	38	100	85	185
5.0	41.0	15	59.0	25	77.0	40	104	90	194

°C = Degrees Celsius = 5/9 (°F - 32).
°F = Degrees Fahrenheit = 1.80 (°C) + 32.

Climate

A National Weather Service weather station has been in continuous operation at or near its present location (sec. 8, T. 65 N., R. 1 W.) at Porthill since 1889. Weather at the station (altitude, 1,775 feet) is representative of weather on the lowlands throughout the project area.

The mean annual temperature at Porthill is 7.2° C (Celsius). January has the lowest (-4.6° C) and July the highest (19.2° C) mean monthly temperature (fig. 4). The average date of the last freeze in the spring is May 14; that of the first freeze in the fall is September 20. This results in an average freeze-free growing season of 129 days (Stevlingson and Everson, 1968).

The mean annual precipitation at Porthill is 20.02 inches. July has the lowest (0.87 inch) and November the highest (2.56 inches) mean monthly precipitation. The amount of precipitation during the average freeze-free growing season is about 5.5 inches, or 28 percent of the annual total (fig. 4.)

Well-Numbering System

The well-numbering system used by the Geological Survey in Idaho indicates the location of wells within the official rectangular subdivision of the public lands, with reference to the Boise base line and meridian. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters and a numeral, which indicate the quarter section, the 40-acre tract, the 10-acre tract, and the serial number of the well within the tract, respectively. Quarter sections are lettered a, b, c, and d in counterclockwise order from

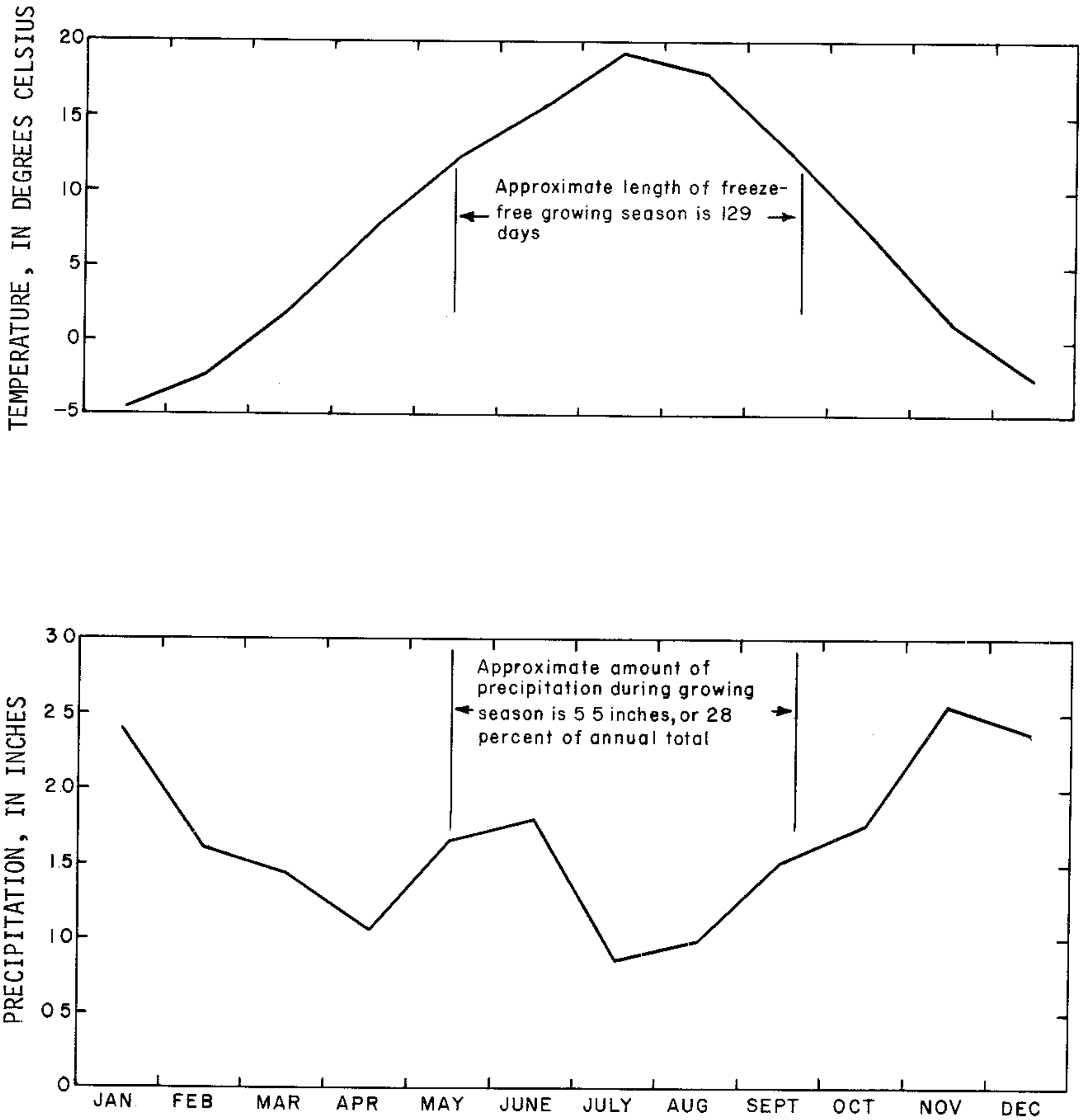

FIGURE 4.--Mean monthly temperature and precipitation at Porthill, Idaho (based on data from National Weather Service for 1890-1971).

the northeast quarter of each section (fig. 5). Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. Well 65N-1W-30bda1 is in the NE¼SE¼NW¼ sec. 30, T. 65 N., R. 1 W., and was the first well inventoried in that tract.

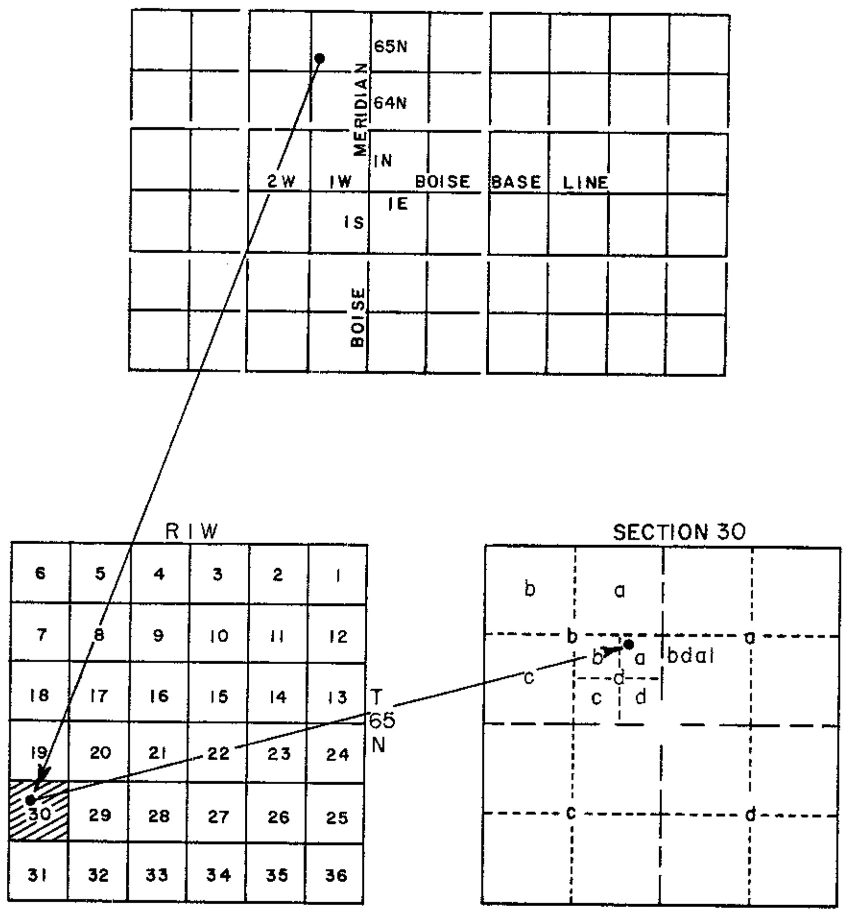

FIGURE 5.--Diagram showing the well-numbering system.
(Using well 65N-1W-30bda1.)

Gaging-Station-Numbering System

Each gaging station and partial-record station has been assigned a number in downstream order in accordance with the permanent numbering system used by the Geological Survey. Numbers are assigned in a downstream direction along the main stream, and stations on tributaries between main-stream stations are numbered in the order they enter the main stream. A similar order is followed on other ranks of tributaries. The complete 8-digit number, such as 12318500 includes the part number "12" plus a 6-digit station number. The part number "12" indicates that the station is in the upper Columbia River basin.

Acknowledgments

The authors express their gratitude to Messrs. Don Howe of the Kootenai Valley Reclamation Association, Don Jensen of the U. S. Soil Conservation Service, and Del Pierce of the Kootenai Wildlife Refuge for their assistance in the well-installation phase of the project; and to the numerous landowners of the Kootenai flats area for their general cooperation and permission to install observation wells on their property.

GEOLOGIC FRAMEWORK

The oldest rock unit exposed in the project area is the Belt Supergroup of Precambrian age. This unit is composed of metamorphosed sediments and underlies the Purcell Mountains and, to a lesser extent, the Selkirk Mountains. The Belt Supergroup in the Purcell Mountains has been only slightly metamorphosed and sills of gabbro and diabase have been intruded into the lower part of the unit. The Belt Supergroup in the Selkirk Mountains has been highly metamorphosed. The total thickness of the Belt Supergroup in northern Idaho is about 30,000 feet (Kirkham and Ellis, 1926).

The greater part of the Selkirk Mountain range is underlain by the Idaho batholith of Early and Late Cretaceous age. Where exposed, this igneous body is composed of granite, granodiorite, and quartz monzonite. The Belt Supergroup and Idaho batholith probably underlie the entire study area at depth and bound the troughlike Purcell Trench in which younger sediments were deposited.

Some question exists as to whether the Purcell Trench was formed by fluvial erosion, faulting, glacial scour, or a combination of these factors. The various theories of origin are discussed in detail in Alden (1953) and are not repeated in this report.

Silts, sands, and gravels of Pleistocene age form the prominent terraces that occur near Bonners Ferry and between Bonners Ferry and Porthill (Porthill bench). The maximum thickness of the sedimentary deposits in the terraces is about 300 feet.

The youngest rock unit in the study area is the fluvial and lacustrine clay, silt, and fine sand of Pleistocene and Holocene age which is exposed in the banks and flood plain of the Kootenai River. The thickness of the fine-grained sediments, as well as the nature of the materials that underlie them, is unknown.

GENERAL HYDROLOGY

Surface Water

Kootenai Valley is drained by the Kootenai River and several large tributaries (fig. 3). Flow in the Kootenai River near Copeland (fig. 6) averages about 15,700 cfs (cubic feet per second); flows in some of the larger tributaries, such as Boundary Creek (fig. 7), average more than 190 cfs. In general, streams draining the western flank of the Purcell Trench (Selkirk Mountains) have higher flows and yields than streams draining the

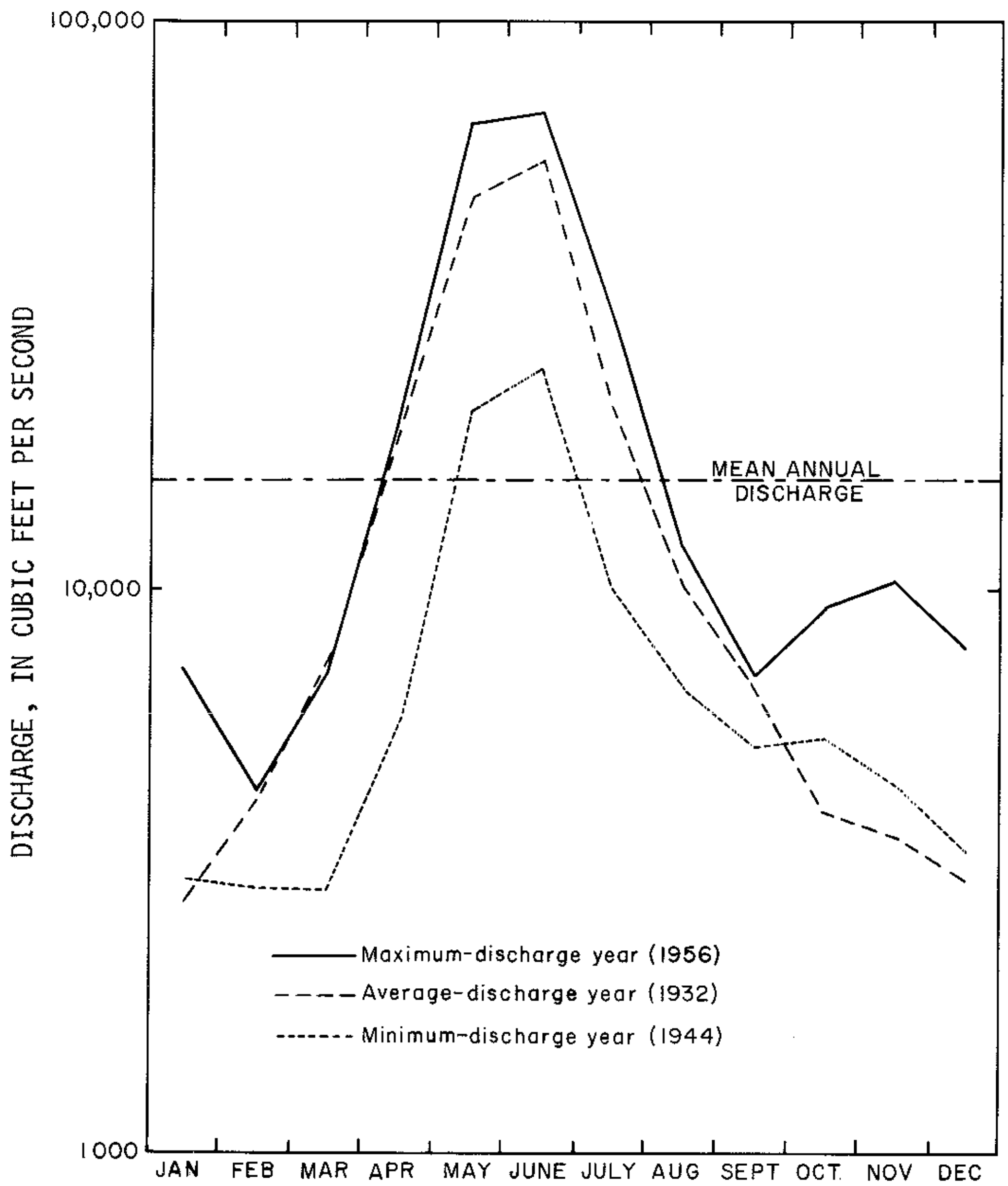

FIGURE 6.--Mean monthly discharge of Kootenai River near Copeland (12318500) for selected years.

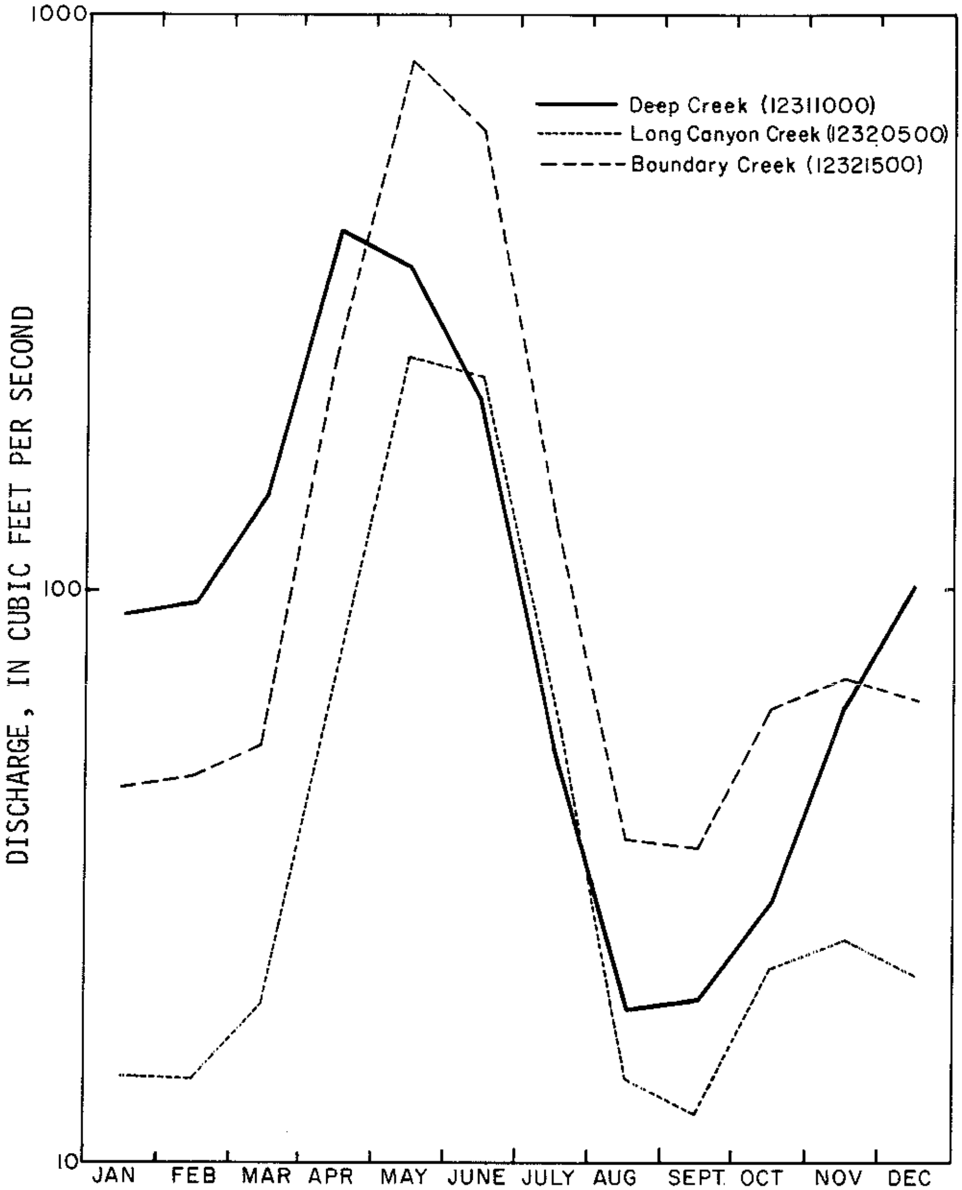

FIGURE 7.--Mean monthly discharge of selected tributaries of the Kootenai River (based on data for water years 1931-59).

eastern flank (Purcell Mountains). Discharge data for streams draining the Purcell Mountains were too scanty for inclusion in figure 7.

The stage of the Kootenai River between Bonners Ferry and Kootenay Lake is controlled not only by the discharge of the river but also by the stage of Kootenay Lake. Because the backwater effects of Kootenay Lake extend all the way to Bonners Ferry, the profile of the water surface between the two places is very flat. Through the years, dikes have been constructed on the natural river levees with the result that, except when a dike breaks, flood waters seldom inundate the flood plain.

The natural flow of Kootenai River follows an annual cycle of considerable regularity. The greatest discharges of the year are caused by melting of snow at high altitudes. As spring approaches, snowmelt causes the river to rise (figs. 6 and 10) until the maximum flow is reached, usually in June. Thereafter, the flow generally decreases with minor fluctuations until the following spring. The tributaries follow the same general flow pattern (fig. 7), but with much less predictability.

Ground Water

This study is concerned primarily with the ground water in aquifers underlying the flood plain of the Kootenai River, or the Kootenai flats. Ground water occurs in the clays, silts, and fine sands of Pleistocene and Holocene age under water-table and artesian conditions. Some of the shallow wells installed in 1930 and some of the wells drilled as part of this investigation tap local, weak artesian zones but the water does not flow at ground surface. Such wells are often difficult to distinguish from nearby water-table wells strictly on the basis of water levels. In addition, the fine materials, especially the clays, yield water very slowly, and it is difficult to determine at the time of drilling when and where water has been encountered. These factors make the delineation of artesian zones extremely difficult.

Recharge to the aquifers is mainly by downward percolation of precipitation and snowmelt and by seepage from Kootenai River and its tributaries. This recharge usually occurs in the late fall, winter, and early spring. Other lesser amounts of recharge are supplied by the natural influx of ground water from surrounding areas and, probably, the upward leakage of water from deeper formations. As part of this investigation, two wells were drilled at the same location but with different depths. One well (62N-1E-8ccc1) is 33.5 feet deep and is finished in silty clay. The other well (62N-1E-8ccc2) is 59.0 feet deep and is finished in coarse gravel with clay. On November 18, 1971, the water level in the deeper well was 1.6 feet higher than that in the shallower well (see Appendix B), indicating that, locally, a potential exists for the upward movement of water.

Near the channel of the Kootenai River, the aquifer is recharged in part by seepage from the river during periods of high river stage, usually May and June. An examination of hydrographs of wells installed in 1930 indicates that the effects of recharge from this source are damped with distance and cannot be detected more than about 3,000 feet from the river.

Under natural conditions, highest water levels in wells away from the river occur in late winter and early spring, immediately following the period of greatest recharge; lowest water levels occur in the fall following the dry season. Water levels in wells away from the river are influenced primarily by melting of the snowpack on the Kootenai flats, the discharge of tributary streams carrying low-altitude snowmelt, and evapotranspiration. Variations in the arrival time of warm weather in the spring generally cause variations in the time of highest ground-water levels.

The hydrographs of wells in levee areas (fig. 8) show a strong similarity to hydrographs of the Kootenai River in that water levels in these wells are usually highest in late spring when river stages are also highest. Although recharge from low-level snowmelt also affects wells in the levee areas, this recharge effect is almost overshadowed by the influence of recharge from the Kootenai River. Peak flows in the Kootenai River are caused by high-altitude snowmelt and generally occur after the low-altitude snowpack has melted away.

Ground-water levels beneath the Kootenai flats in the spring are generally too high for optimum farm operation except where artificial drainage programs are enacted.

The fine-grained alluvial sediments beneath the Kootenai flats transmit water to wells very slowly. The transmissivity of the sediments was not determined as part of this study because of the almost complete lack of data concerning the nature and thickness of the valley fill beneath the relatively shallow, fine-grained sediments. Based on the nature of these sediments, the transmissivity may be quite small; that is, from less than 100 to a few hundred square feet per day and that the storage coefficient may be approximately 0.025. These values are intuitive estimates only and measured values may differ significantly from them. In addition, areal differences in these properties should be expected.

No information is available concerning the quality of the water in the fine-grained sediments of the Kootenai flats. This is due to the general

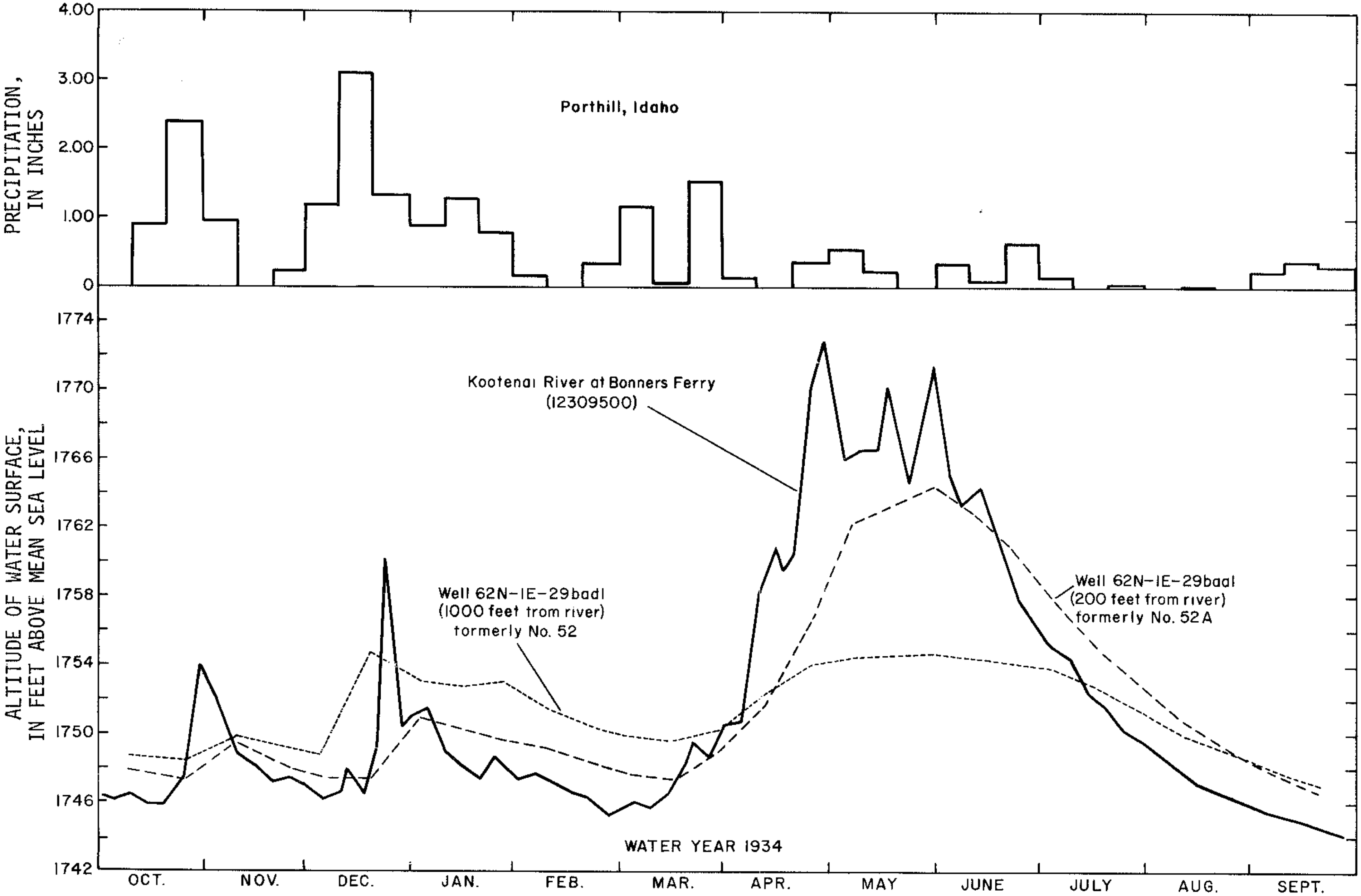

FIGURE 8.--Hydrographs of precipitation at Porthill, stage of the Kootenai River, and of water levels in selected wells for water year 1934 (location of wells shown on fig. 3).

lack of productive wells in the study area.

Ground water beneath the Kootenai flats moves slowly through the fine-grained sediments to the closest points of discharge, namely, drains, stream and river channels, and areas of evapotranspiration. During long periods of high river stage, the water table slopes downward and away from both the river channel and the surrounding foothills; during long periods of low river stage, the water table slopes downward from the foothills all the way to the river channel. The preparation of a water-level contour map proved impractical because of a lack of control to define the numerous irregularities in the ground-water surface. Natural ground-water discharge to the Kootenai River occurs only when the stage of the river is below the level of the water table in the shallow aquifer. The lowest lands on the Kootenai flats are between the foothills and the levees (now dikes). The water level beneath these low lands is very close to and at times above land surface even when evapotranspiration losses are heavy during the growing season.

PREVIOUS INVESTIGATIONS

Detailed geologic descriptions of the Kootenai flats are few. Kirkham and Ellis (1926) described the geology and ore deposits of Boundary County. Alden (1953) described the physiography and glacial geology of western Montana and northern Idaho. Neither investigation placed any particular emphasis on the Kootenai flats.

Most of the hydrologic data and all of the ground-water data now available which pertains to the Kootenai flats were collected by the Geological Survey. The ground-water data were collected during 1928-58 as part of an investigation of the effects of river stage on the ground-water system of the

Kootenai flats.

On September 6, 1929, the West Kootenay Power and Light Company, Ltd., a Canadian firm, applied to the International Joint Commission for permission to construct a dam on the West Arm of Kootenay Lake. An open meeting was held in Bonners Ferry, Idaho, on November 6, 1929, for the airing of objections to the proposal. The principal result of the meeting was to initiate additional, long-term studies by the Geological Survey concerning the effects of lake (river) regulation on the ground-water system of the Kootenai flats. The dam in question was built in 1931 near Corra Linn, west of Nelson, British Columbia. For the first few years of operation, the dam was used for power production only and with the gates left open. Later, the dam was used to effect storage in Kootenay Lake under a plan of operation supervised by the International Joint Commission.

The Geological Survey's program of hydrologic investigation and basic-data collection on the Kootenai flats was completed under the supervision of T. R. Newell of the Geological Survey. Some of the prominent features of Newell's studies were (1) the installation and monitoring of 300 shallow observation wells; (2) a detailed study of the relation of river stage and ground-water levels; (3) the classification of Kootenai flats lands into "levee," "critical," and "other" areas, based on depth of the water table on April 1, 1930; and (4) modified water budgets for the "critical" areas.

Although the Kootenai investigation resulted in several interpretive and basic-data reports, these reports were never formally published. A list of the reports and other materials that resulted from the investigation and which are available for inspection in the Boise office of the U. S. Geological Survey is presented in Appendix A. Much additional information, chiefly in the form of minor reports, basic data, maps, and memorandums was sent to the National Archives and Records Service, Seattle, Washington, in 1966. A list of the materials sent to the archives is available for inspection in the Boise office of the U. S. Geological Survey.

OBSERVATION-WELL NETWORK

The principal feature of this investigation was the installation of 84 observation wells to monitor the effects of Libby Dam operation on the ground-water system of the Kootenai flats. The installation of new wells was necessary because of a general lack of production wells in the area and because, as mentioned previously, all the observation wells installed by the Geological Survey in 1930 had either been destroyed or were not available for use.

A geographic location for each of the new wells was first selected in the office on topographic maps and then checked in the field. The three principal factors that determined the locations of the wells were (1) an arbitrarily determined density of at least one well per square mile of bottomland; (2) easy accessibility to the wells throughout most of the year; and (3) duplication of as many of the 1930 well sites as was practical. The density of the completed well network is 1.2 wells per square mile, or one well per 0.8 square mile of bottomland. To provide maximum accessibility, all wells were placed within easy walking distance of an established road or farm lane. No wells were knowingly placed in cultivated fields where they would interfere with farm operations. Forty of the new wells duplicate 1930 well sites to within a horizontal distance of 0.1 mile and a vertical distance of 10 feet (land-surface altitude). The locations of the new observation wells are shown in figure 3.

The depth to which each of the new wells was to be drilled was determined by a study of the water-level fluctuations measured in the old (1930) wells. An attempt was made to drill the new wells just deep enough so that the water level would not drop below the top of the well screen at any time. Wells meeting this requirement were drilled at 82 sites. The depths of the wells range from 15.3 to 52.5 feet and average 27.6 feet. In addition, at two of the sites (65N-1W-19aca and 62N-1E-8ccc), wells 75.7 and 59.0 feet deep, respectively, were installed to determine if differences in water level (pressure) existed with depth (see p. 17). The records of the Kootenay flats observation wells are listed in Appendix B.

The 84 observation wells were installed during a 3-week period in late August and early September 1971. Details of typical well installations are given in figure 9. Generally, a 6-inch diameter hole was augered to a pre-determined well depth with a truck-mounted power auger. The 79 wells to be measured periodically with a steel tape were constructed of 1¼-inch galvanized pipe. Water-level measurements are made through a wye about 4 feet above land surface. A 5-foot length of pipe above the wye serves as a mast for a highly-visible fluorescent orange flag. The mast is capped, but in times of unusually deep snow the water level could be measured by removing the cap and inserting the measuring tape through the mast. A block of wood bolted to the well casing at ground level retards settling of the pipe. The five wells to be equipped with continuous recorders were constructed of 4-inch PVC (polyvinyl chloride) pipe. A separate, 15-foot length of pipe was installed 0.5 feet away (center-to-center) to accommodate the counterweight of the recorder. Continuous recorders were installed on three of five

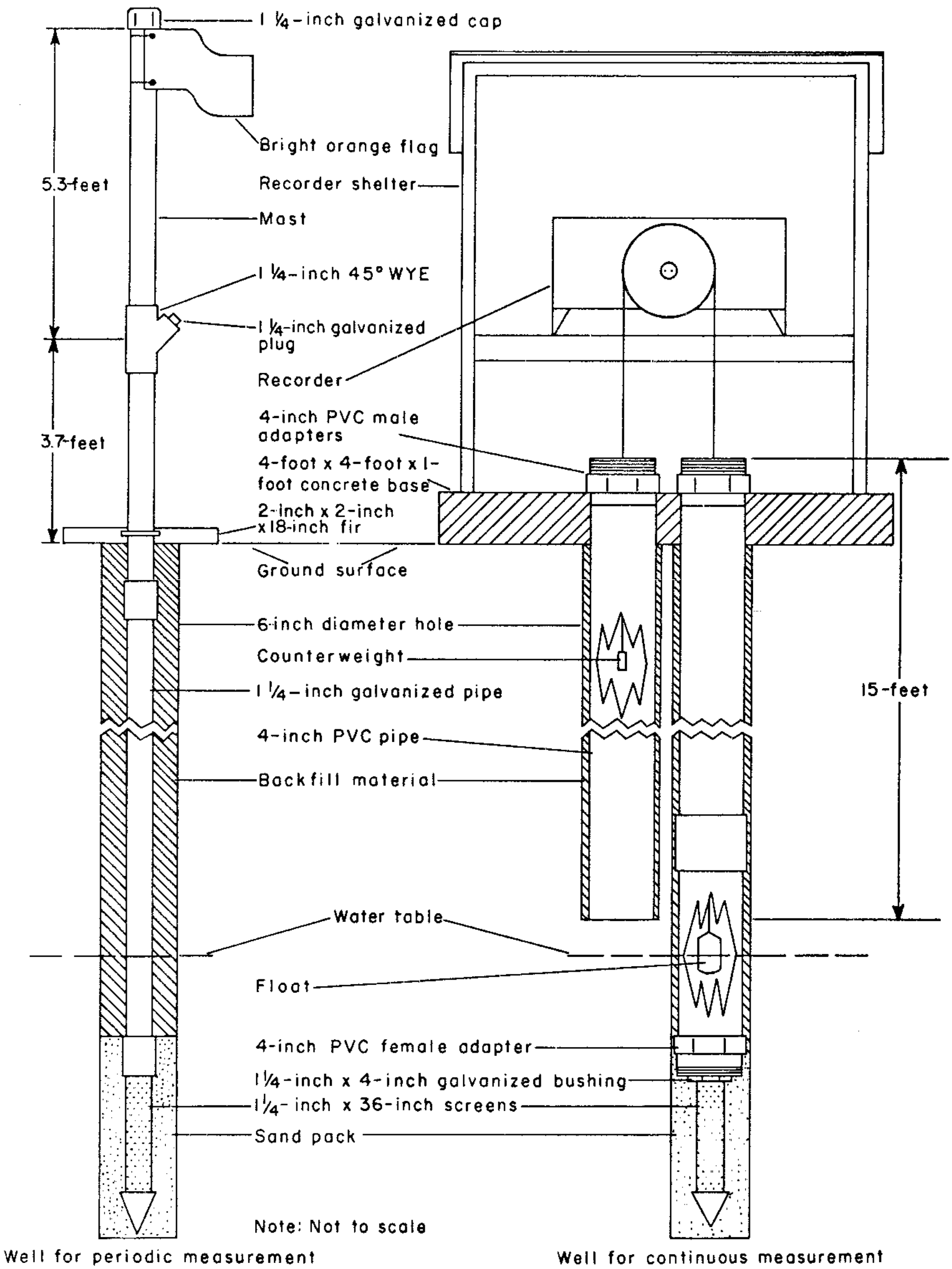

FIGURE 9.--Diagram of typical well installation.

wells so constructed. At each of the recorder sites, a concrete base was poured around the well and counterweight hole to provide support for a recorder shelter and recorder. Both the periodic- and continuous-measurement wells were finished with 40- or 60-gauze brass well screens (sand points) 1¼ inch in diameter and 3 feet long. The annular space between the screen and the wall of the 6-inch hole was filled with sand and then the remainder of the annular space was backfilled to land surface with soil and clay.

The altitudes of the land surface and of the measuring point at each well site were established to an accuracy of 0.01 foot. Each well was "slug" tested with a known volume of water to determine the degree of hydraulic connection with the aquifer. Only one well (65N-1W-27bbc1) was found to be completely sealed from the aquifer. Attempts to break the seal proved futile and until stronger methods can be used, or the well redrilled, the well in question is not being used for observation purposes.

As part of this investigation, water levels in the observation wells, exclusive of the three wells with continuous recorders, were measured by the wetted-tape method once each month through June 1972. The three continuous-measurement wells are equipped with Stevens type A-35 recorders. The operation of the recorders is checked once each month and the strip charts are usually replaced at that time.

All physical, geologic, and water-level data pertaining to the observation wells have been coded so that they may be placed on punch cards for computerized manipulation.

In November 1971, the U. S. Army Corps of Engineers installed five shallow observation wells near Bonners Ferry. The locations of the wells are shown in figure 3. Water-level measurements are presently being made in the wells on a regular basis by personnel of the U. S. Geological Survey.

WATER-LEVEL TRENDS AND FLUCTUATIONS

One of the principal factors in determining the locations of the new observation wells was the recovery of as many 1930 well sites as possible (p. 21). The well table in Appendix B lists the numbers of 40 old-well sites that were recovered and data pertaining to the equivalent new wells. Water levels at seven of the old sites had been monitored by the Geological Survey over an extended period (1930-54). The hydrographs of the seven wells for the 25-year period are presented in figure 10. In addition, water levels measured as part of this study in the seven new, equivalent wells are plotted for comparison. Although the measurements in the new wells are too few to establish definite water-level trends and fluctuations, it appears that no significant water-level changes have occurred near the seven wells since measurements were discontinued in 1954.

The amplitudes of water-level fluctuations that can be expected in the new wells will depend in part on the locations of the wells. In those wells that are influenced by the stage of Kootenai River, the amplitudes of seasonal water-level fluctuations should decrease as seasonal river-stage fluctuations are decreased (fig. 2) by the operation of Libby Dam.

In wells that are not influenced by the river stage, seasonal water-level fluctuations should remain about the same as those measured between 1930 and 1954 (5-15 feet), provided that the same amount of water is artificially drained from the bottomlands as was prior to 1954.

Since 1965, drainage district 7 (fig. 3) has been used as a wildlife refuge, primarily for migratory waterfowl. Increasingly since that time, surface-water levels in the district have been controlled at unnaturally high levels for the benefit of the waterfowl. It is reasonable to assume, therefore, that ground-water levels are being influenced by this operation and that the water levels measured in the new wells in that district will not correlate with those measured prior to 1965.

CONCLUSIONS AND RECOMMENDATIONS

The principal objective of this study was to construct a network of observation wells that would monitor the effects of Libby Dam operation on the ground-water system of the Kootenai flats. This objective was accomplished by the installation of the 84 observation wells described in this report and listed in Appendix B.

Data collected during the installation of the wells indicate that the ground water beneath the Kootenai flats is locally very shallow and that the aquifers penetrated contain fine-grained materials. A review of the water-level data collected from wells installed in 1930 indicates that the effects of recharge from the Kootenai River cannot be detected beyond distance of about 3,000 feet from the river. It is reasonable to conclude, therefore, that the effects of recharge from the river will be detected only in those new wells that are within about 3,000 feet of the river. Other wells may be affected indirectly, however, because higher post-Libby Dam river stages will reduce natural ground-water discharge to the river throughout most of the year. Unless pumping is increased to offset these conditions, post-Libby Dam ground-water levels beneath the Kootenai flats will generally be higher than before Libby Dam operation began.

The water-level measurements in the new observation wells are too few to establish definite trends. It appears likely, however, that no significant water-level changes have occurred in the Kootenai flats area since measurements were discontinued in 1954.

Water levels in the new observation wells should be measured at least bimonthly for an extended period. Once the magnitude of seasonal fluctuations and the water-level trends have been established, a comparison with pre-Libby Dam conditions should be made to determine the hydrologic effects, if any, of the dam on the shallow ground-water system.

A program of deep test drilling and geophysical surveying, or both, should be completed to determine the depth and nature of the sediments that underlie the Kootenai flats and the presence or absence of aquifers at depth. The information collected in such studies might be useful in determining some of the causes of, and possibly some solutions to, the chronic drainage problems of the Kootenai flats. For instance, if deep aquifers do exist and hydraulic pressures there are greater than in the shallow aquifers, then recharge from this source to the shallow aquifers probably occurs. Such a situation could be a cause of the drainage problem. Reduction of the pressure, possibly by pumping, would reduce recharge to the shallow aquifers and aid drainage operations. If, on the other hand, hydraulic pressures in the deep aquifers are less than in the shallow aquifers, additional drainage could probably be effected with the use of deep, gravity drain wells.

A hydrologic model, either digital or analog, of the Kootenai flats area should be constructed. The chief purposes of such a model would be to define the relation between river stage and ground-water levels, to determine the causes of any changes in ground-water levels observed, and to predict water-level changes based on given sets of hydrologic conditions.

The existing data pertaining to ground-water levels, river stage, lateral boundaries, and precipitation are sufficient to allow construction of a preliminary model. However, to refine the model and realize its full potential, additional data pertaining to the thickness, nature, and hydrologic properties of sediments at depth, the locations and effects of artificial drains, the rates of evaporation and transpiration, and the sources and amounts of recharge would have to be collected.

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Anderson, A. L., 1927, Some Miocene and Pleistocene drainage changes in northern Idaho: Idaho Bur. Mines and Geology Pamph. 18, 29 p.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., 534 p.

Kirkham, V. R. D., and Ellis, E. Q., 1926, Geology and ore deposits of Boundary County, Idaho: Idaho Bur. Mines and Geology Bull. 10, 78 p.

Ross, C. P., and Forrester, J. D., 1958, Outline of the geology of Idaho: Idaho Bur. Mines and Geology Bull. 15, 74 p.

Stevlingson, D. J., and Everson, D. O., 1968, Spring and fall freezing temperatures in Idaho: Idaho Agr. Expt. Sta. Bull. 494, 19 p.

APPENDIX A

APPENDIX A

UNPUBLISHED REPORTS AND OTHER MATERIALS PERTAINING TO THE KOOTENAI FLATS AVAILABLE FOR INSPECTION IN THE BOISE, IDAHO, OFFICE OF THE U. S. GEOLOGICAL SURVEY

Interpretive Reports

Alden, W. D., 1931, Geology and physiography of the Kootenai River valley in northwestern Montana, northern Idaho, and Kootenay district, British Columbia: U. S. Geol. Survey, 42 p.

Davenport, R. W., 1933, Effects of proposals in the application of the West Kootenay Power and Light Company, Ltd., on water levels of the Kootenai River in the United States: U. S. Geol. Survey, 16 p.

Newell, T. R., 1933a, Effects of proposed regulated water levels, Kootenai River, on water table and drainage outlets, Kootenai Valley Drainage Districts: U. S. Geol. Survey, 86 p.

______ 1933b, Ground-water report, Kootenai River investigation, memorandum relative to District No. 4: U. S. Geol. Survey, 34 p.

______ 1933c, Ground-water report, Kootenai River investigation, memorandum relative to District No. 7: U. S. Geol. Survey, 58 p.

______ 1934, Supplemental report, Kootenai River investigation, water table and drainage outlets, Kootenai Valley Drainage Districts: U. S. Geol. Survey, 50 p.

U. S. Geological Survey, 1929, Statement relative to application of West Kootenay Power and Light Company for permit to regulate flow from Kootenay Lake, with special reference to the effects in Idaho: 30 p.

______ 1931, Progress report - Kootenai River investigation, Part I -

Interpretive Reports (Cont'd.)

Manuscript section of report: 151 p.

______ 1934, Memorandum to the Chief Hydraulic Engineer concerning statements in the R. W. Crowe brief regarding ground-water evidence presented to International Joint Commission, August 24-26, 1933: 89 p.

West Kootenay Power and Light Company, Ltd., 1932, Drainage districts, Kootenai Valley, Idaho - discussion of the water table in its relation to the river, foothills, and drain ditches: 126 p.

Basic-Data Reports

U. S. Geological Survey, 1931a, Compilation of streamflow records, pt. II of Progress report, Kootenai River investigation: 167 p.

______ 1931b, Data related to ground-water study, pt. III of Progress report, Kootenai River investigation: 150 p.

______ 1931c, Compilation of base data relating to Kootenai River investigation: 332 p.

______ 1933a, Streamflow, Kootenai River and tributaries, Leonia, Idaho, to Porthill, Idaho, v. I of Compilation of base data relating to Kootenai River investigation: 222 p.

______ 1933b, Kootenai River cross sections, Bonners Ferry, Idaho, to Kootenay Lake, British Columbia, v. II of Compilation of base data relating to Kootenai River investigation: 158 p.

______ 1933c, Topography and ground-water observations, Kootenai Valley Drainage Districts, Bonners Ferry, Idaho, v. III of Compilation of base data relating to Kootenai River investigation: 191 p.

______ 1933d, Climate and drainage, Kootenai Valley Drainage Districts, Bonners

Ferry, Idaho, v. IV of Compilation of base data relating to Kootenai River investigation: 110 p.

______ 1934, Streamflow, Kootenai River and tributaries, Leonia, Idaho, to Porthill, Idaho; Ground water, climate and drainage observations, Kootenai Valley Drainage Districts, Bonners Ferry, Idaho, v. V of Compilation of base data relating to Kootenai River investigation: 130 p.

______ 1937, Streamflow, Kootenai River and tributaries, Leonia, Idaho, to Porthill, Idaho; Ground water, climate, and drainage observations, Kootenai Valley Drainage Districts, Bonners Ferry, Idaho, v. VI of Compilation of base data relating to Kootenai River investigations: 247 p.

______ 1941, Streamflow, Kootenai River and tributaries, Leonia, Idaho, to Porthill, Idaho; Ground water, climate and drainage observations, Kootenai Valley Drainage Districts, Bonners Ferry, Idaho, v. VII of Compilation of base data relating to Kootenai River investigation: 243 p.

______ (no date), Well observations, 1938-58, Kootenai Valley, Idaho.

______ (no date), Computation of averages, critical wells, 1930-38, Kootenai Valley, Idaho.

______ (no date), Computation of averages, critical wells, 1939-47, Kootenai Valley, Idaho.

______ (no date), Computation of averages, levee and other areas, 1930-38, Kootenai Valley, Idaho.

______ (no date), Computation of averages, levee and other areas, 1939-47, Basic-Data Reports (Cont'd.)

Kootenai Valley, Idaho.

West Kootenay Power and Light Company, 1932a, Engineering data, Kootenay Lake storage: 164 p.

______ 1932b, Engineering data, Kootenay Lake storage: 126 p.

______ 1933, Engineering data, Kootenay Lake storage: 78 p.

Miscellaneous Reports

Crowe, R. C., 1932, Amended application of West Kootenay Power and Light Company, Ltd., to the International Joint Commission for approval of works in the Kootenai River and for the right to store water in Kootenay Lake: 11 p.

______ 1934, Kootenay Lake storage application; brief of West Kootenay Power and Light Company, Ltd., presented to the International Joint Commission: 99 p.

International Joint Commission, 1936, The Kootenai Valley - a report on certain cases involving reclamation and the development of water power in the valley of the Kootenay River, under the terms of Article IV of the treaty of January 11, 1909: 374 p.

Read, K. C., 1934, Reply brief filed on behalf of the Government of Canada in the matter of the amended application of the West Kootenay Power and Light Company, Ltd., to the International Joint Commission for storage privileges in Kootenay Lake: 30 p.

U. S. Geological Survey, 1966, Thirty years on the Kootenai, 1928-58; a review of Kootenai investigation files: 69 p.

Maps and Photographs

Map folio I, dated May 1933. Nine topographic sheets with ground-water wells located and soil conditions sketched. Scale: 1 to 12,000. Contour interval: 2 feet (2 copies).

Aerial photographs, dated May 1956. Four photographs at a scale of 1 to 1,334. Altitude of camera: 8,000 feet.

APPENDIX B

APPENDIX B

RECORDS OF OBSERVATION WELLS ON KOOTENAI FLATS

Type of aquifer: 1, very fine grained; 2, fine grained; 3, medium grained; 4, coarse grained; 6, clayey; 7, silty; 8, sandy; G, gravel; P, clay; Q, silt; S, sand

Drainage district: K.K.G.A., Kootenai Kattle Grazing Association

				Water-level measurement				
Well No.	Altitude of land surface (feet)	Depth (feet)	Type of aquifer	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date	Drainage district	Equivalent 1930 well number
65N- 2W-11daa1	1,755.84	17.1	Q	8.87	1,746.97	11-16-71	K.K.G.A.	-
12daa1	1,753.69	25.9	6Q	7.93	1,745.76	11-16-71	K.K.G.A.	-
13bab1	1,761.16	27.5	6Q	15.12	1,746.04	11-16-71	K.K.G.A.	-
24bbc1	1,751.53	21.8	4S	4.78	1,746.75	11-16-71	Thorman	-
24dbb1	1,760.48	31.3	6Q	15.96	1,744.52	11-16-71	Thorman	-
65N- 1W 8cbc1	1,756.33	26.2	8Q	10.59	1,745.74	11-16-71	8	288
18daa1	1,751.94	26.1	P	6.68	1,745.26	11-16-71	8	283
19aca1	1,750.20	17.0	P	4.57	1,745.63	11-16-71	8	-
19aca2	1,750.24	75.7	P	4.91	1,745.33	11-16-71	8	-
20dcd1	1,756.04	29.4	7P	13.72	1,742.32	11-16-71	8	-
27bbc1[a]	1,757.49	40.8	-	-	-	-	6	255
27ddd1	1,749.90	26.8	P	5.82	1,744.08	11-16-71	6	239
30bda1	1,761.78	26.2	6Q	13.92	1,747.82	11-16-71	8	250
30bdb1	1,753.82	36.0	P	8.47	1,745.35	11-16-71	10	249-A
30cdc1	1,749.78	21.4	7P	4.31	1,745.47	11-16-71	10	-
31add1	1,757.90	31.9	7P	11.92	1,745.98	11-16-71	10	-
33aaa1	1,761.02	36.0	7P	18.58	1,742.44	11-16-71	6	236
33acc1	1,760.29	26.1	6Q	11.71	1,748.58	11-16-71	6	221
33bbb1	1,753.26	20.8	8Q	11.81	1,741.45	11-16-71	6	234
35dab1	1,748.83	16.8	P	4.48	1,744.35	11-16-71	6	-

RECORDS OF OBSERVATION WELLS ON KOOTENAI FLATS (Cont'd.)

Well No.	Altitude of land surface (feet)	Depth (feet)	Type of aquifer	Water-level measurement: Depth to water (feet below land surface)	Water-level measurement: Altitude of water surface (feet)	Water-level measurement: Date	Drainage district	Equivalent 1930 well number
64N- 1W- 1bdd1	1,756.31	36.3	7P	14.77	1,741.55	11-17-71	6	202
1cbc1	1,755.53	26.6	P	11.73	1,743.84	11-17-71	6	-
2bbb1	1,752.09	21.2	7P	6.38	1,745.71	11-16-71	6	210
2cbb1	1,757.39	21.2	8Q	11.95	1,745.44	11-16-71	6	199
3bbb1	1,750.04	16.3	6Q	7.46	1,742.58	11-16-71	6	-
3cbc1	1,753.82	18.6	2Q	7.17	1,746.65	11-16-71	13	-
5aad1	1,762.33	26.6	Q	15.30	1,747.03	11-16-71	10	207
5dca1	1,771.59	21.7	4S	7.76	1,763.83	11-16-71	10	-
10ada1	1,764.70	25.9	Q	18.70	1,746.00	11-16-71	6	-
10dbb1	1,762.25	25.9	Q	14.33	1,747.92	11-16-71	13	176
11dcd1	1,756.09	21.1	8Q	9.32	1,746.77	11-16-71	9	-
12cbb1	1,763.19	26.8	Q	13.41	1,749.78	11-17-71	6	179
12ddd1	1,760.45	26.4	7P	13.38	1,747.07	11-18-71	4	-
13aba1	1,765.31	26.1	2S	18.78	1,746.53	11-16-71	9	-
13ddc1	1,755.09	40.9	7P	8.84	1,746.25	11-18-71	4	-
14bdd1	1,756.11	21.8	7S	9.53	1,746.58	11-16-71	9	161
24dac1	1,757.29	26.1	P	11.92	1,745.37	11-18-71	4	-
25ccc1	1,756.87	21.1	3S	9.92	1,746.95	11-17-71	16	-
25cdc1	1,754.24	21.1	1S	7.70	1,746.54	11-17-71	16	-
36aaa1	1,763.14	46.5	7P	15.18	1,747.96	11-18-71	4	137
36bdd1	1,764.39	26.2	1S	17.89	1,746.50	11-17-71	16	-
64N- 1E-18cda1	1,759.26	21.6	Q	3.82	1,755.44	11-18-71	4	159
30dcc1	1,753.88	40.9	7P	7.07	1,746.81	11-18-71	4	139
31aab1	1,756.05	22.1	P	5.44	1,750.61	11-18-71	4	140
31ccc1	1,766.35	26.3	7P	14.05	1,752.30	11-18-71	4	130

RECORDS OF OBSERVATION WELLS ON KOOTENAI FLATS (Cont'd.)

Well No.	Altitude of land surface (feet)	Depth (feet)	Type of aquifer	Water-level measurement: Depth to water (feet below land surface)	Water-level measurement: Altitude of water surface (feet)	Water-level measurement: Date	Drainage district	Equivalent 1930 well number
63N- 1W-12acd1	1,754.61	26.4	7P	3.25	1,751.36	11-17-71	12	-
13acd1	1,759.28	25.9	7P	13.33	1,745.95	11-17-71	12	-
24acb1	1,757.74	30.8	2Q	8.02	1,749.72	11-17-71	12	-
25daa1	1,766.38	26.4	2S	19.78	1,746.60	11-18-71	5	-
36baa1	1,753.77	30.9	P	6.47	1,747.30	11-17-71	3	110
36dab1	1,760.79	26.7	8P	13.29	1,747.50	11-17-71	3	-
63N- 1W- 6dba1	1,762.33	46.2	7P	16.13	1,746.20	11-18-71	Castillo	-
18bab1	1,764.23	25.9	3S	18.00	1,746.23	11-18-71	-	-
30caa1	1,762.10	30.8	7P	11.00	1,751.00	11-18-71	5	117
30daa1	1,755.38	25.6	8Q	7.30	1,748.08	11-18-71	5	118
31cdd1	1,766.73	31.5	7P	16.43	1,750.30	11-18-71	11	101
32ccd1	1,760.70	40.7	6Q	10.84	1,750.06	11-18-71	11	-
62N- 1W- 1caa1	1,765.79	31.1	8P	19.23	1,746.56	11-17-71	3	95
12bdd1	1,770.14	31.1	Q	23.07	1,747.07	11-18-71	11	-
12ddd1	1,761.99	26.6	3S	12.11	1,749.88	11-17-71	7	77
13bab1	1,756.52	21.3	P	6.84	1,749.68	11-17-71	7	-
13ccd1	1,754.55	16.7	P	1.49	1,753.06	11-17-71	7	61
24ddc1	1,754.02	15.3	P	.83	1,753.19	11-17-71	7	-
62N- 1E- 6cdd1	1,755.40	21.6	P	9.27	1,746.13	11-18-71	11	92
7cdd1	1,769.58	36.6	S	22.43	1,747.15	11-17-71	7	79
7dcd1	1,767.75	30.3	7P	14.13	1,753.62	11-18-71	11	-
8bab1	1,757.97	17.5	P	9.93	1,748.04	11-18-71	11	94
8ccc1	1,753.52	33.5	P	6.71	1,746.81	11-18-71	11	-
8ccc2	1,753.55	59.0	6G	5.11	1,748.44	11-18-71	11	-
17ada1	1,752.16	25.8	P	2.01	1,750.15	11-18-71	11	-

RECORDS OF OBSERVATION WELLS ON KOOTENAI FLATS (Cont'd.)

Well No.	Altitude of land surface (feet)	Depth (feet)	Type of aquifer	Water-level measurement: Depth to water (feet below land surface)	Water-level measurement: Altitude of water surface (feet)	Water-level measurement: Date	Drainage district	Equivalent 1930 well number
62N- 1E-19bba1	1,760.93	27.4	P	12.05	1,748.88	11-17-71	7	65
19bda1	1,769.62	25.5	Q	20.03	1,749.59	11-18-71	11	-
20bbb1	1,752.95	26.7	7P	4.32	1,748.63	11-18-71	11	66
20dba1	1,764.97	26.4	7P	10.13	1,754.84	11-18-71	11	-
23ccd1	1,762.17	26.5	6S	11.07	1,751.10	11-18-71	2	-
24cba1	1,767.61	39.3	P	14.85	1,752.76	11-18-71	2	-
28bbc1	1,771.12	36.2	P	23.77	1,747.35	11-17-71	1	53B
29cbb1	1,753.79	25.6	S	6.01	1,747.78	11-17-71	1	41
30aaa1	1,765.52	41.1	P	17.34	1,748.18	11-17-71	1	51
30ccc1	1,762.51	28.2	8P	12.30	1,750.21	11-17-71	1	26
32ccd1	1,750.46	25.5	8P	3.07	1,747.39	11-17-71	1	11
33abb1	1,750.69	19.7	P	2.43	1,748.26	11-17-71	1	31
33cdd1	1,758.26	25.6	P	9.05	1,749.21	11-17-71	1	14
61N- 1E- 9bac1	1,758.40	52.5	P	13.74	1,771.66	11-17-71	1	-

[a] *Well plugged.*

UNITED STATES DEPARTMENT OF THE INTERIOR
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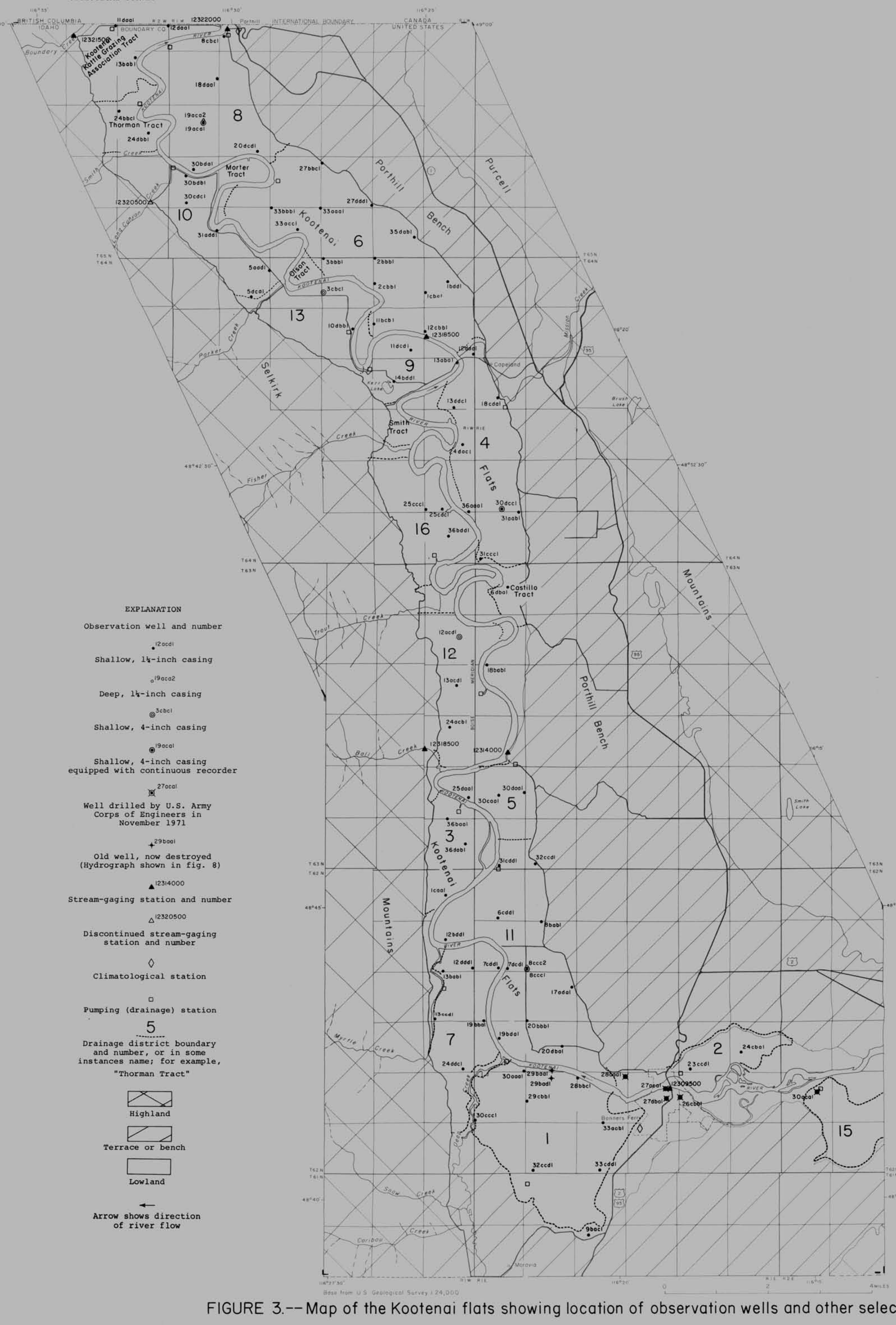

FIGURE 3.--Map of the Kootenai flats showing location of observation wells and other selected data.

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FIGURE 10.--Hydrographs of precipitation at Porthill, stage of the Kootenai River at Bonners Ferry, and of water levels in selected wells for periods 1930-54 and 1971-72.